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AIRFIELD BOMB DAMAGE REPAIR METHODS, (U)
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(6) AIRFIELD BOMB DAMAGE
REPAIR METHODS,

by

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(12) 27

(11) December 1980

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Washington, D. C. 20314

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Foreword

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This report is intended to present a field reference document on airfield repair depicting "how-to-do-it" for troop training. Three repair solutions were selected for presentation. The methods of repair were obtained from information derived from work accomplished by U. S. Army engineer units in the field (particularly, the 18th Engineer Brigade and the 293rd Engineer Battalion) and by full-scale testing conducted at the U. S. Army Engineer Waterways Experiment Station (WES). This report was written by Mr. P. J. Vedros, Jr., of the Geotechnical Laboratory (GL), WES, under the general supervision of Mr. A. H. Joseph and Dr. G. M. Hammitt of the Pavement Systems Division, GL.

Commander and Director of the WES during the preparation of this document was COL Nelson P. Conover, CE. Technical Director was Mr. Fred R. Brown.

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Conversion Factors, U. S. Customary to Metric (SI)
Units of Measurement

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
cubic yards	0.7645549	cubic metres
feet	0.3048	metres
gallons per square yard	4.5273	cubic metres per square metre
inches	25.4	millimetres
pounds (force) per square inch	0.6894757	newtons per square square centimetre

AIRFIELD BOMB DAMAGE REPAIR METHODS

Introduction

Purpose

1. The purpose of this manual is to present current available information to units in the field on how to repair and restore a war-damaged airfield. Three repair solutions are offered, and the choice of solution will depend on resources, mission requirements, and extent of damage. The methods, materials, and techniques presented are for airfield runways, taxiways, aprons, and roadways.

Background

2. The ability of the Air Force to achieve and maintain air superiority in the support of the ground conflict is dependent on the rapid return of runways to operation after an enemy attack. Runways are not usually destroyed by an enemy attack but are rendered temporarily inoperable by bomb craters, surface damage from cannon fire, and large amounts of debris. Limited operations can resume as soon as a 50- by 5000-ft* emergency strip is repaired (Figure 1). The construction effort required will necessitate combined efforts of U. S. forces and participation of host nations. The Army engineer forces have the following responsibilities: providing repair/restoration of war damage to airbases beyond that of emergency repair, assisting the Air Force in the emergency repair when that requirement exceeds the Air Force in-service organic capability, base development excluding Air Force beddown responsibilities, and construction management of repair/restoration of war damage and base development. In addition to paved surfaces, the Army is also responsible for the acquisition, repair, improvement, expansion, and rehabilitation and construction of installations and facilities to support existing and deploying Air Force units. This support consists of rehabilitation/construction of facilities such as supply depots;

* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

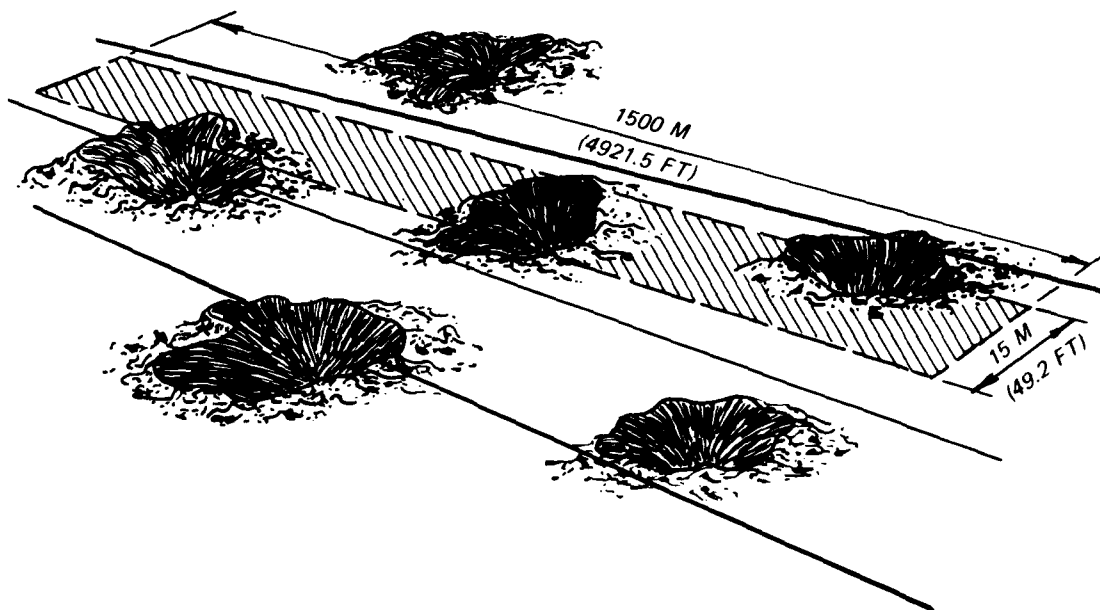


Figure 1. Operational area on a bomb-damaged runway

petroleum, oil, and lubricants (POL) systems; and buildings and roads conforming to theater of operations (TO) standards of construction.

3. The Air Force engineering units have the responsibility for the emergency repair to the extent necessary to accomplish the air mission. The Air Force also has the responsibility for force beddown of Air Force units and weapons systems, operation and maintenance of Air Force installations, crash rescue and suppression, and construction management of emergency repair of war damage and force beddown.

4. Host nations have the responsibilities for providing engineering support at colocated operating bases (CLOB) within the theater and other support activities as agreed.

Prestrike planning

5. The ability to recover and restore is a function of two factors, the preattack preparedness and the extent of the damage. The preattack preparedness consists of planning and familiarization with all types of constructed facilities, utility systems, essential support

systems, and availability of equipment and construction materials.

6. Availability of equipment. The type and number of equipment available should be considered, as well as the location of this equipment, i.e., where it is stored or available when needed. Some planning should be considered to keep this equipment in a condition of readiness at all times.

7. Availability of local host nation support. The support provided by the host nation in equipment, construction materials, and personnel should be considered in all prestrike planning.

8. Availability of construction materials. The location of sources of construction materials as to type and quantity should be planned. Alternate sources may be required. The location of prestocked repair materials should be identified as to type and quantity available.

9. Drainage and utility systems. Construction drawings should be available showing the location of surface and subsurface drainage systems and the location of valve, breakers, or backup systems for utility systems.

Postattack planning

10. The situation immediately after an initial attack necessarily includes the extent of damage to the paved surfaces, as well as equipment damage, casualties, the potential for followup attack, unexploded ordnance, and climatological factors. Obstacles to effective recovery encountered in the postattack environment should be considered in evaluating the difficulties of operating effectively in a potentially traumatic situation. The following paragraphs indicate the type of planning and surveys that need to be accomplished prior to the actual repair of a bomb-damaged crater in the airfield pavement.

11. Repeated attacks. Repeated attacks should be anticipated. Proper planning should include the protection of repair personnel and equipment against repeated attacks.

12. Unexploded ordnance. Unexploded ordnance, as well as followup attacks, will be effective in rendering initial repair efforts especially hazardous. Some expedient measures can be taken to render equipment more suitable for working in this environment. Although ordnance disposal

teams will be effective in removal of unexploded ordnance, engineer personnel can aid in the removal and ensure additional personal safety by attempting to explode some surface ordnance with such equipment as organic compaction equipment either pushed ahead of a prime mover or towed across the runway at the end of long cables. Some of the engineer equipment, such as front-end loaders, graders, and crawler tractors, can be hardened somewhat by the addition of sheet metal cabs and wheel protectors as can be designed and installed onsite.

13. Physical damage to pavements. If one assumes several large and small bombs and other ordnance such as cannon fire on a paved surface, it is reasonable to assume that a total of 5 to 25 percent of a surface could sustain damage requiring repair (Figure 2). The probable volume of ejecta commensurate with this damage could be up to 6000 cu yd or an average of up to 8 in. in depth over the entire runway or taxiway area. Since many of the craters can be expected to have a depth in excess of the thickness of the pavement structure, the ejecta will consist of all materials from all pavement components, in addition to the in situ subgrade material (Figure 3). These combined effects could require an extensive ejecta removal and backfill operation prior to the actual repair of either the large or small craters.

14. Drainage facilities. Restoration or repair of drainage facilities that have been destroyed or damaged in an attack will normally be considered low priority in the postattack situation. However, where precipitation is imminent or at least probable, lack of drainage could greatly increase the efforts needed to restore a facility and could possibly preclude successful restoration. Those facilities warranting particular attention are the shallow side ditches that carry the airfield surface runoff. Since some of the material could be utilized for crater backfill, the most likely time for regrading or cleaning drainage ditches would be in conjunction with the runway cleanup operation.

15. Reserve personnel and equipment. Although it appears obvious that all available personnel and equipment will be required in the repair operation, the feasibility of holding a reserve capability should

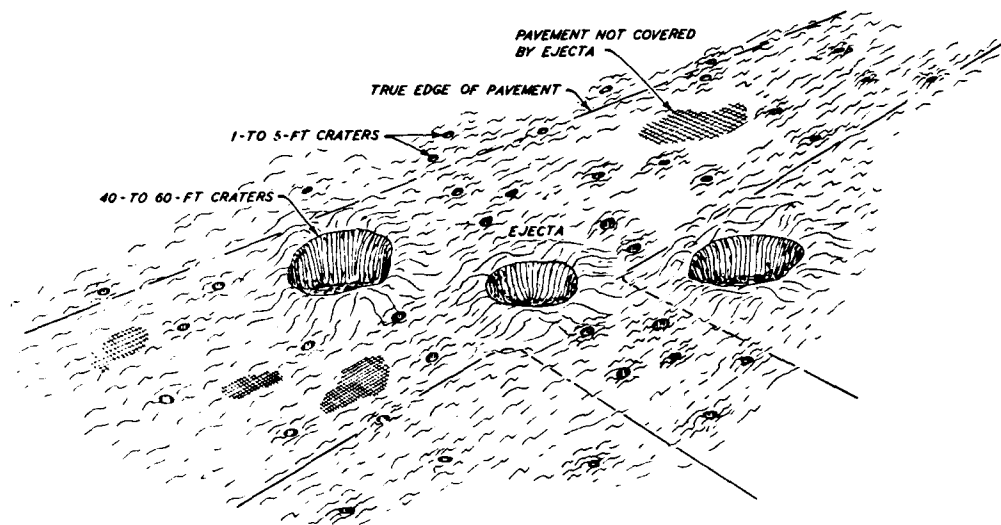


Figure 2. Perspective view of damage
at a runway-ramp intersection

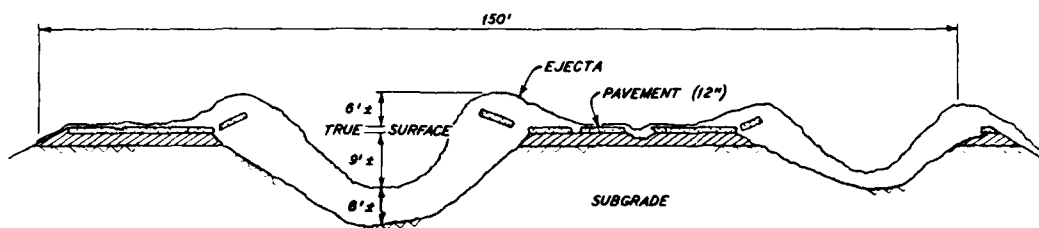


Figure 3. Cross-sectional view of damaged area

be considered by each organization; and when it is considered possible, such a capability should be maintained.

16. Contingency planning and operation. It is prudent to expect that onsite equipment will sustain damage to some extent during an attack. Where possible, equipment should be located in remote onsite locations, in shelters, or concealed by some means. The greatest potential damage is the threat of attacks during the repair operation. Special recovery equipment may be needed to remove disabled heavy equipment such as tractors and compactors. Planning that includes such considerations is essential.

Selection of repair procedure

17. In the selection of a repair procedure, numerous factors must be considered. Chief among these is the availability of personnel, equipment of the proper type, and the repair material itself. These considerations are then subject to the constraints imposed by the postattack situation and the climatic conditions. The following paragraphs present some factors that affect the choice of repair methods to be employed.

18. Pavement type. Although most of the methods suggested can be employed to repair craters in all pavement types, certain factors might limit their effectiveness. Therefore, to the greatest extent practicable, the repair structure should be similar to the existing pavement structure. The landing mat repair method will apply equally to all pavement types.

19. Crater size. The crater size and quantity play an important role in selection of repair methods. In the case of large craters requiring large volumes of various materials, care should be taken to use the materials that can best be handled in larger quantities. If time is the controlling factor, the special rapid-curing materials must become the obvious choice. In the case of small craters and even smaller surface potholes and spalls caused by cannon fire and small explosives, the more rapid-curing materials that can be quickly prepared, transported, and placed will prove more desirable.

20. Availability of materials, equipment, and personnel. When constrained by any of these factors, the decision process simply consists

of using what is available, regardless of other considerations. However, the type of equipment and the number of trained personnel could influence the method of repair selected. Less personnel specialization would be required for transporting and placing crushed stone than for use of some of the exotic materials.

21. Time constraints. Probably the most critical of all factors is the time constraint that will be assigned to the overall restoration procedure. Decisions will be required in some instances to employ the more temporary and rapid procedures in order to make it possible for a few aircraft to operate on the facility in a very short time frame. Plans can be made for upgrading the repairs at the earliest opportunity.

22. Weather. Extreme weather conditions can be a major factor in the successful repair of craters using most of the methods and materials available. Heavy rainfall can severely reduce the quality of the usable backfill material and make necessary its replacement with less water-susceptible materials. Excessively hot temperatures will cause accelerated setting of some of the time-sensitive, rapid-curing compounds. Extreme cold will retard the setting and curing of portland cement concrete (PCC) as well as some of the rapid-set materials. Accelerators, such as calcium chloride, should be available as needed.

23. Equipment with pneumatic tires. The operation of this equipment may be hindered by tire failure resulting from pieces of shrapnel and debris scattered throughout the repair area. Special tires, i.e., foam-filled, may reduce the hazard.

Repair Solutions

Full-depth coarse aggregate solution

24. Quality of coarse aggregate. The crushed stone must be well graded and of high quality to perform successfully in this type of repair. Material conforming to the following considerations will provide a satisfactory base course to carry the proposed aircraft loads:

- a. Well-graded, coarse to fine.
- b. Maximum size of coarse aggregate not to exceed 1-1/2 in.

- c. Between 15 and 40 percent passing the No. 10 sieve.
- d. Not more than 10 percent passing the No. 200 sieve.
- e. Plasticity index not more than 5.

25. Thickness of crushed stone required. To minimize material handling, the crushed stone should be stockpiled adjacent and parallel to the runway or taxiway. Approximately 50,000 cu yd is required to be stockpiled for anticipated use at an airfield. The minimum thickness required for rapid bomb damage repair is shown in the following tabulation:

Foundation Strength	Aircraft	Full-Depth Crushed Stone in.	Flexible Pavement in.	Concrete Pavement*
Weak clay	F4	24	28	14
material	C-141 & F4	38	44	15
Medium clay	F4	16	18	13
granular	C-141 & F4	21	24	14
mixture				
High clay	F4	12	14	12
granular	C-141 & F4	15	18	12
material, low fines				

* Requires 24 in. of crushed stone base.

26. Procedure. The repair procedure consists of filling the crater with ejecta to within the required thicknesses (see paragraph 25). The selected ejecta (any material larger than 12 in. moved to side of runway) are pushed into the crater (Photo 1), then spread and lightly compacted by a dozer (Photo 2). The crushed stone is then placed in the crater in lift thicknesses that can be compacted readily by available compaction equipment. The crushed stone can be end-dumped from the sides of the crater (Photo 3) and spread with a dozer (Photo 4) or spread in the crater by trucks entering and leaving the crater. Equipment placing aggregate in this manner will aid in the compaction process. The lower 12-in. thickness should be compacted to approximately 95 percent of CE 55 modified density. The top 12-in. layer should be

compacted to 100 percent or greater of CE 55. The number of passes of a roller to achieve this compaction effort will depend on materials, moisture conditions, roller weight, and tire pressures (Photo 5). It is sometimes difficult to adequately compact in some areas of the crater with the large compaction equipment, then it will be necessary to use hand compactors in these areas (Photo 6). The final lift of crushed stone should be overbuilt by 2 to 3 in.; after compaction, it should be bladed off flush with the surface (Photo 7) and compacted again with the heavy roller (Photo 8). A well-graded, high-quality crushed stone does not require a surfacing layer except for prevention of foreign object damage (FOD). A surface layer of emulsified asphalt, sprayed at the rate of 0.1 to 0.3 gal/sq yd and sealed with a sand blotter course, can be applied to the crushed stone with an asphalt distributor or with portable sprayers (Photo 9). If available and time allows, a 4-in. thickness of high-quality, hot-mix asphaltic concrete can be placed as a surface. Another surfacing material that can be considered is mixing at least 10 percent of a Type III or Bn 550 PCC in the top 6-in. layer of crushed stone. The cement can be blade-mixed, wetted, and compacted.

Rigid pavement solution

27. The rigid pavement solution consists of first preparing the crater with selected ejecta material, then selected aggregate base course material, and finally placing a PCC cap surface. This type of repair is permanent and can only be used where sufficient time is available to allow the concrete to set to the minimum required compressive strengths of approximately 1000 psi.

28. Unsuitable ejecta (material too large) is removed from the crater with a dozer, and suitable debris material is pushed into the crater with front-end loaders and dozers. The material is placed in the crater to a depth of 36 in. below the existing concrete surface and compacted to a minimum of 85 percent of CE 55 modified density. In small craters where compaction equipment cannot be used, this percent density is difficult to achieve. Normally, where a dozer or vibrator can be used, the debris can be satisfactorily compacted. The selected aggregate base course material is end-dumped into the crater with dump

trucks. The selected aggregate must be a high-quality, well-graded stone conforming to the following considerations:

- a. Well-graded, coarse to fine.
- b. Not more than 85 percent passing No. 10 sieve.
- c. Not more than 15 percent passing No. 200 sieve.
- d. Plasticity index not more than 8.
- e. Adequate amount of nonplastic fines is desirable to obtain adequate bonding and compaction.

The selected aggregate is compacted and brought to grade within the minimum thicknesses for concrete pavement (see paragraph 25). The area around the crater surface is cleaned of all loose debris with a rotary broom (Photo 10). The edge of the crater is cleaned with an air compressor to ensure a clean surface for bonding of the concrete (Photo 11). The crater is stringlined for grade, and the screed pedestal is placed in the center of the repair crater (Photo 12). The prefabricated pedestal can be hand carried into place by six persons if a crane is not available. A round steel bar is placed through the center hole of the pedestal for attachment of the screed and trail beams (Photo 13). A headwall board is placed between the pedestal and the outside edge of the crater to form a wall for the concrete to butt up against so that a head can be created in front of the screed beam (Photo 14).

29. The crater is now ready for placement of the rigid pavement capping. The rigid pavement capping may be regulated-set concrete, high-early strength concrete, or Type I PCC, depending on the time available prior to aircraft usage. The pavement capping is placed in the crater from transit trucks (Photo 15). The first truck places its load directly against the headwall board; when enough concrete is in place, the screed board is pulled forward to strike off the concrete flush with the existing pavement (Photo 16). A front-end loader is used to pull screed board (Photo 17). This process continues around the crater until all concrete is placed and screeded. The trail beam is utilized to provide a working platform over the concrete for personnel finishing the concrete surface (Photo 18).

Airfield landing mat solution

30. There are four types of landing mats available for use by troops for emergency runway repairs. These mats are the Army's M8A1, XM18, and XM19 and the Navy's AM-2. As a result of runway repairs, kits using AM-2 mats, ramps, and an anchorage system have been developed and are available. The other mats (M8A1, XM18, and XM19) could be used for emergency repairs as long as the required strength (CBR) of the soil is obtained in the bomb crater fill to support the mat. The CBR values required for each special mat to support the desired number of aircraft operations are shown in the tabulation below. However, repair kits, ramps, and anchorage systems have not been specifically developed for other than the AM-2 mat. Only the AM-2 mat patch kit is recommended for preassembly and towing over the crater to be surfaced. Since the other mats will have to be anchored along the edges of the paved surfaces, they will have to be assembled in place. None of the mat applications would be acceptable for aircraft using hook-arrested landings.

<u>Mat</u>	<u>2100 Operations of F-4E Fighter</u>	<u>280 Operations of C-141 Cargo</u>	<u>Total of Both Aircraft</u>
M8A1	6	8	10
XM18	4	4	5
XM19	3	3	4
AM-2	4	4	5

31. The AM-2 mat repair procedure developed by the Air Force is presented herein for the solution to repairing a crater with landing mat. The AM-2 mat repair package is a depot-stocked item specifically developed by the Navy and consists of a patch assembly measuring 54 by 77.5 ft. In the normal deployment of the mat, the patch is assembled adjacent to the bomb crater either on the edge of the runway or on an undamaged portion of the runway and towed over the filled crater. The procedure for filling the crater with the debris is the same as has been outlined in the paragraphs for the coarse aggregate or rigid pavement solutions. The crater is filled with suitable debris and compacted until the compacted fill reaches a level of 12 in. below the runway surface. The top 12 in. of the crater is filled with crushed stone

screenings or sand. The material is compacted so that it is flush with the runway surface. Be sure to avoid overfilling. While the crater is being filled, an area is selected and cleaned to assemble the mat patch. An area (preferably on the runway if possible) to one side of the crater is selected to allow a straight pull over the filled crater (Figure 4). An alternate but less desirable position for assembly of the mat is shown in Figure 5, i.e., along the center line of the 50-ft runway path. To reduce friction during towing, men using shovels can lift the leading edge of the patch. After the patch is correctly positioned, the ramps are attached and anchored. All materials necessary for assembly, towing, and anchoring of the mat are contained in the repair package.

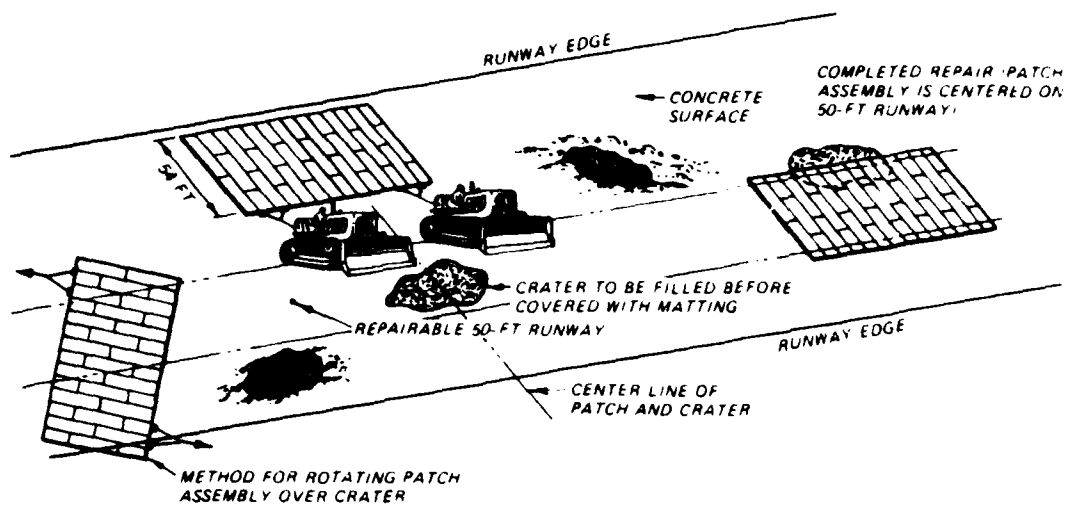


Figure 4. Emergency repair of runway bomb craters. In the foreground is the "patch" which has been assembled from the kit (patch, 50 ft. wide, 54 ft.). After the crater has been filled with earth and crushed rock and properly compacted, the patch is towed into position over the crater by heavy vehicles. In the upper right is a patch already in place.

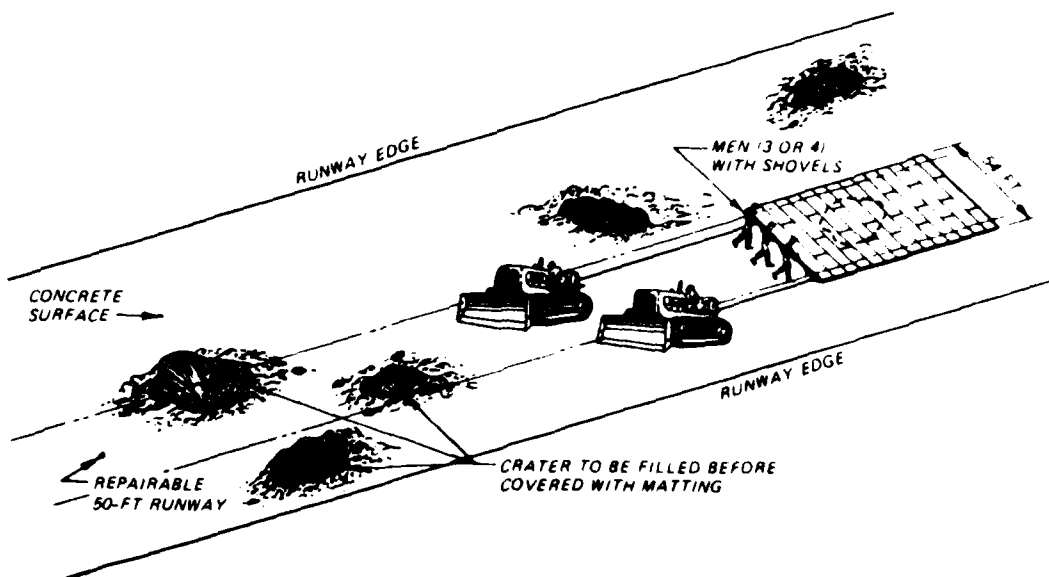


Figure 5. Patch assembled and towed along the center line of the repaired runway

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Photo 1. Selected size ejecta pushed into the crater
and oversize to side of runway

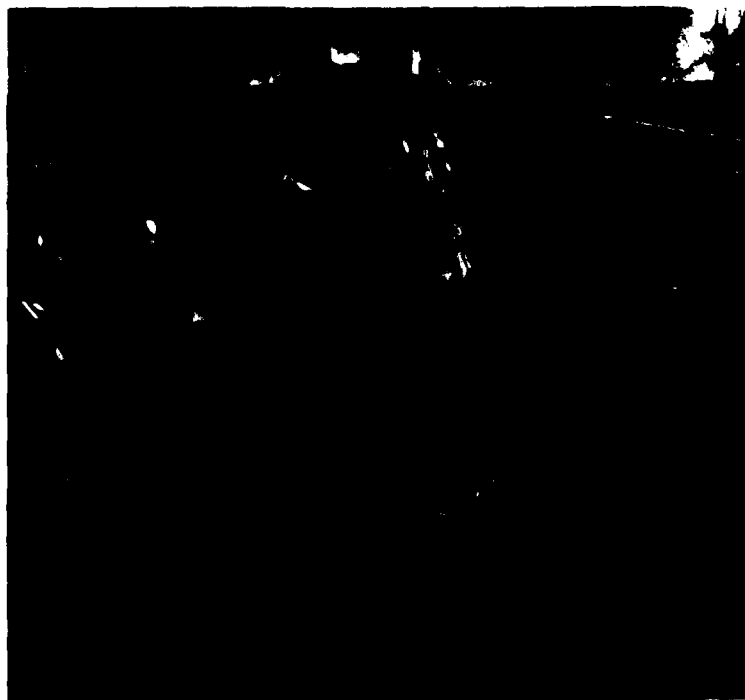


Photo 2. Dozer spreading and lightly compacting ejecta material.

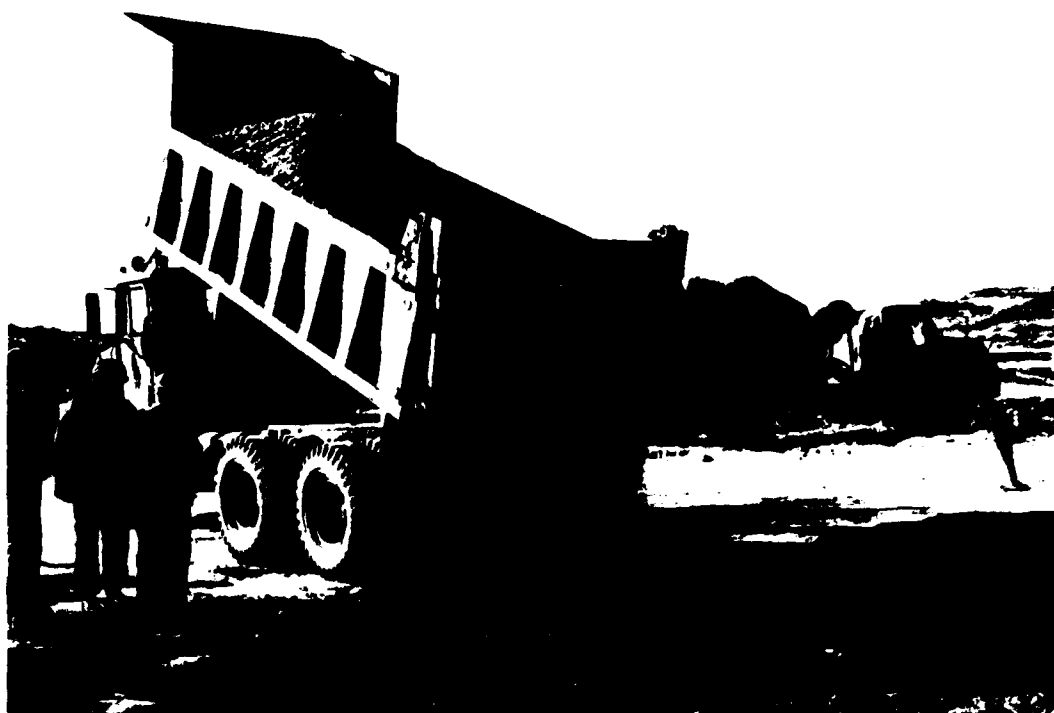


Photo 3. Crushed stone end-dumped from edge of crater



Photo 4. Material spread in lift thicknesses with dozer

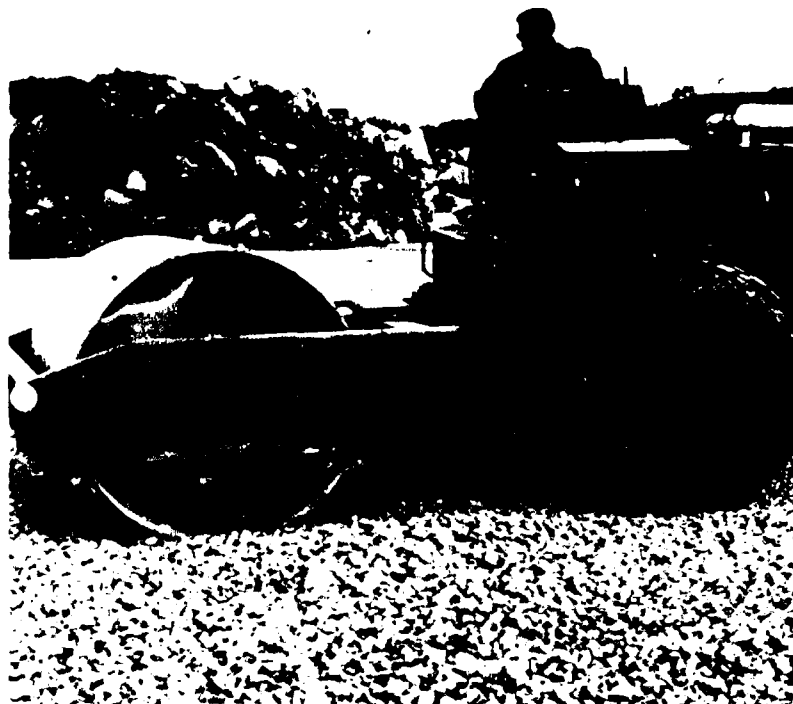


Photo 5. Rolling crushed stone with vibratory roller



Photo 6. Hand-operated tampers used in areas where large compaction equipment could not be used



Photo 7. Crushed stone bladed off flush with pavement surface



Photo 8. Final rolling after crushed stone bladed flush with surface



Photo 9. Hand spraying surface of crushed stone with emulsified asphalt

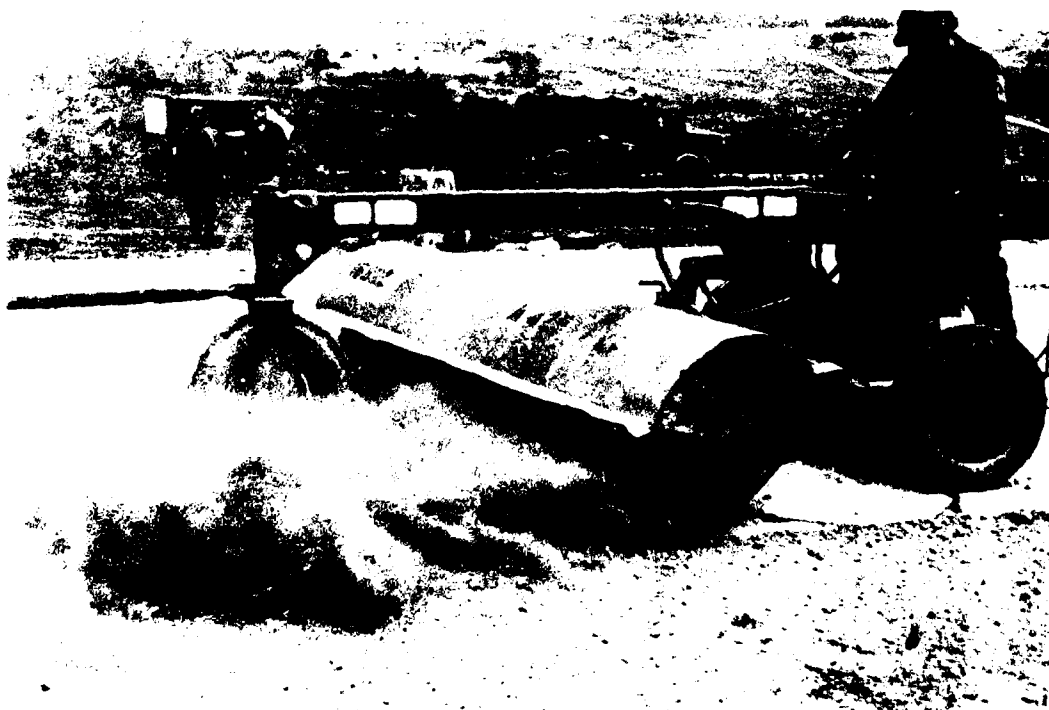


Photo 10. Area around surface of crater cleaned with a rotary broom



Photo 11. Edge of crater cleaned with air pressure
to ensure good bonding of concrete



Photo 12. Screed pedestal placed in center of crater

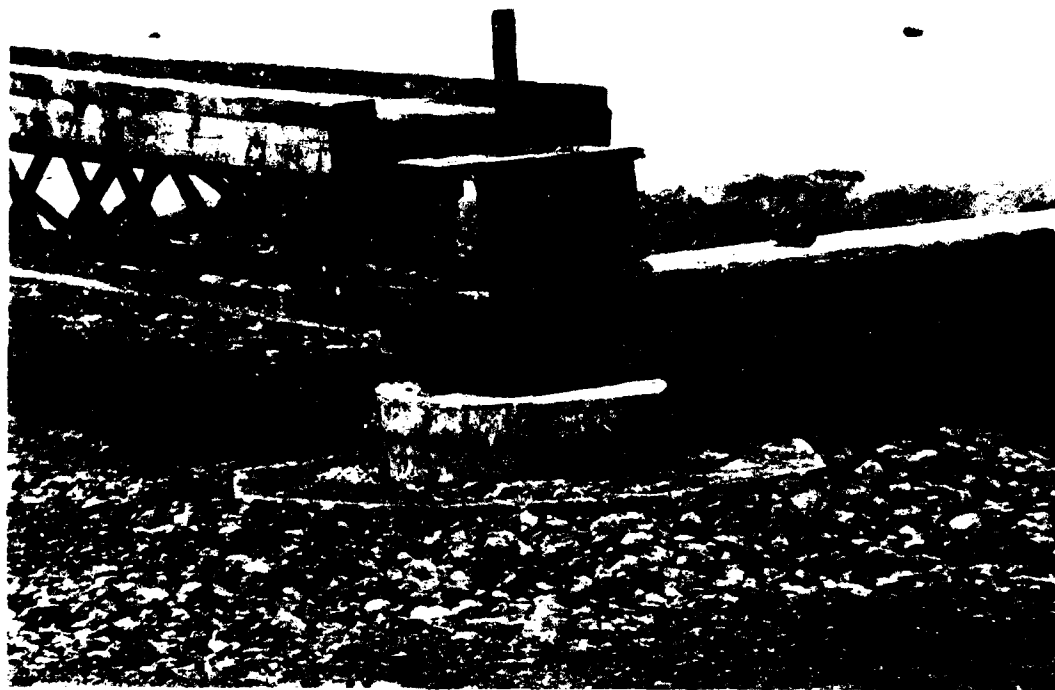


Photo 13. Screed and trail beam attached by means
of a round steel bar at center of pedestal



Photo 14. Headwall board and screed beam



Photo 15. Concrete placed in crater from transit truck



Photo 16. Sereel 1 and pulled forward to screed concrete flush with existing surface

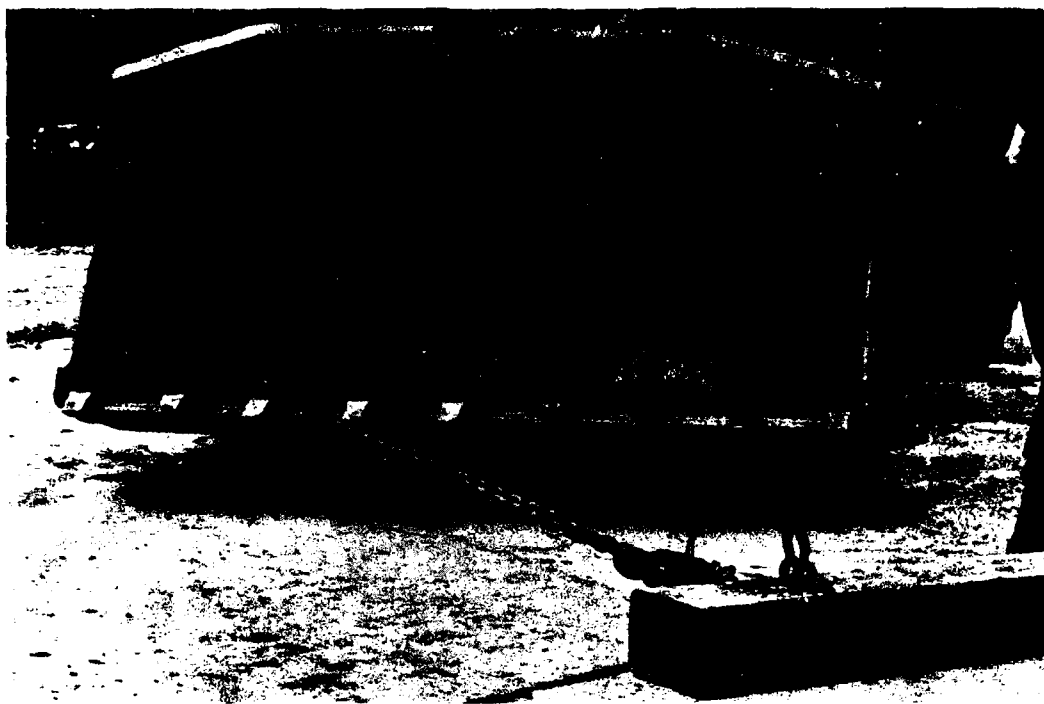


Photo 17. Front-end loader used to pull screed board



Photo 18. Personnel on trail beam finishing concrete surface

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